Automated Software Fault Measurement

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Agenda

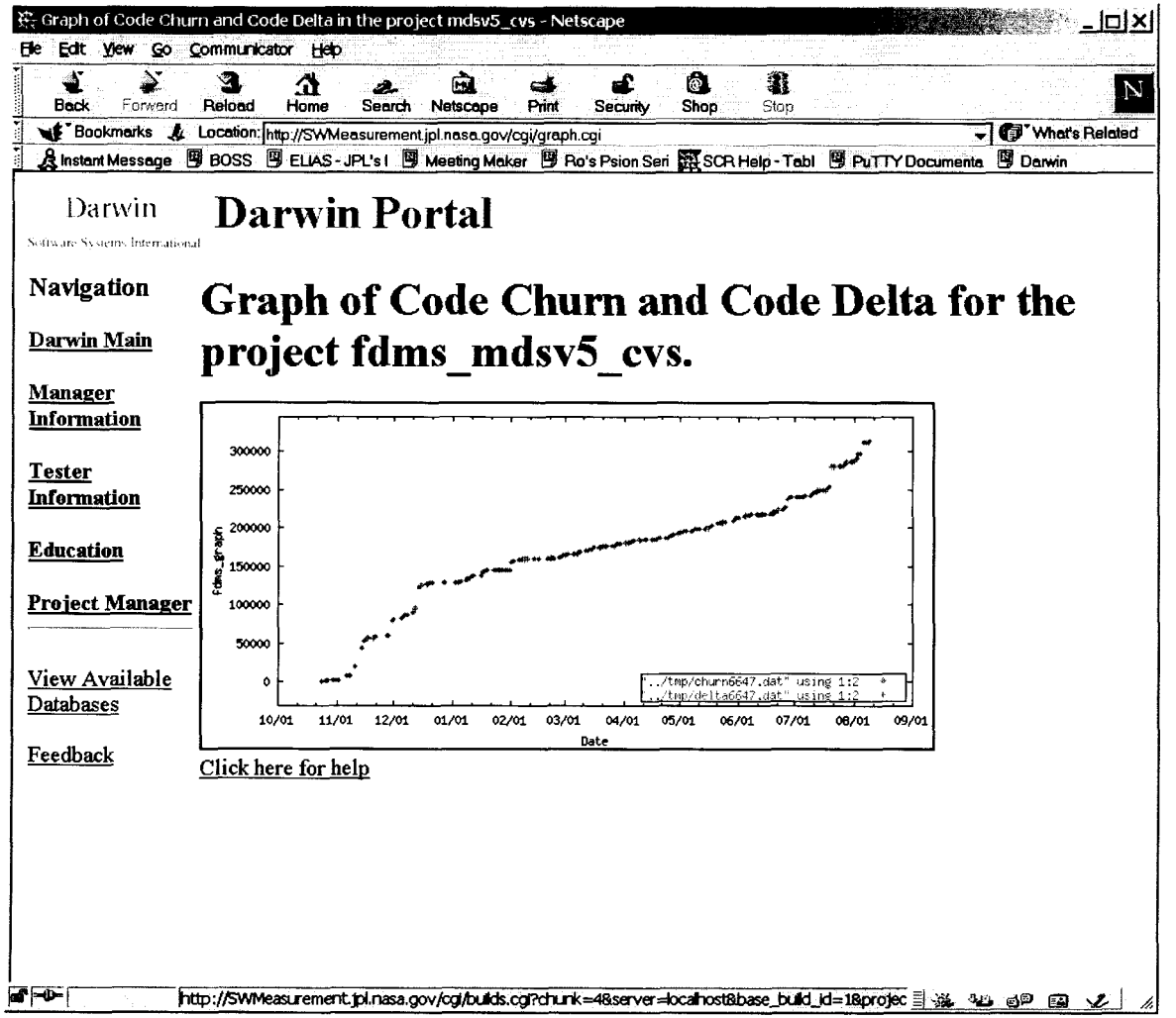
- Motivation
- Current State of Affairs
- Approach
  - Examples
- Identifying and Counting Faults
  - Examples
- Current Work

Motivation

- One goal of current work is to improve understanding of the type of faults that are inserted into a software system during its lifetime by identifying relationships between types of structural change and the number and types of faults inserted.
- Developing software fault models depends on definition of what constitutes a fault
- Desired characteristics of measurements, measurement process
  - Repeatable, accurate count of faults
  - Measure at same level at which structural measurements are taken
    - Measure at module level (e.g., function, method)
  - Easily automated

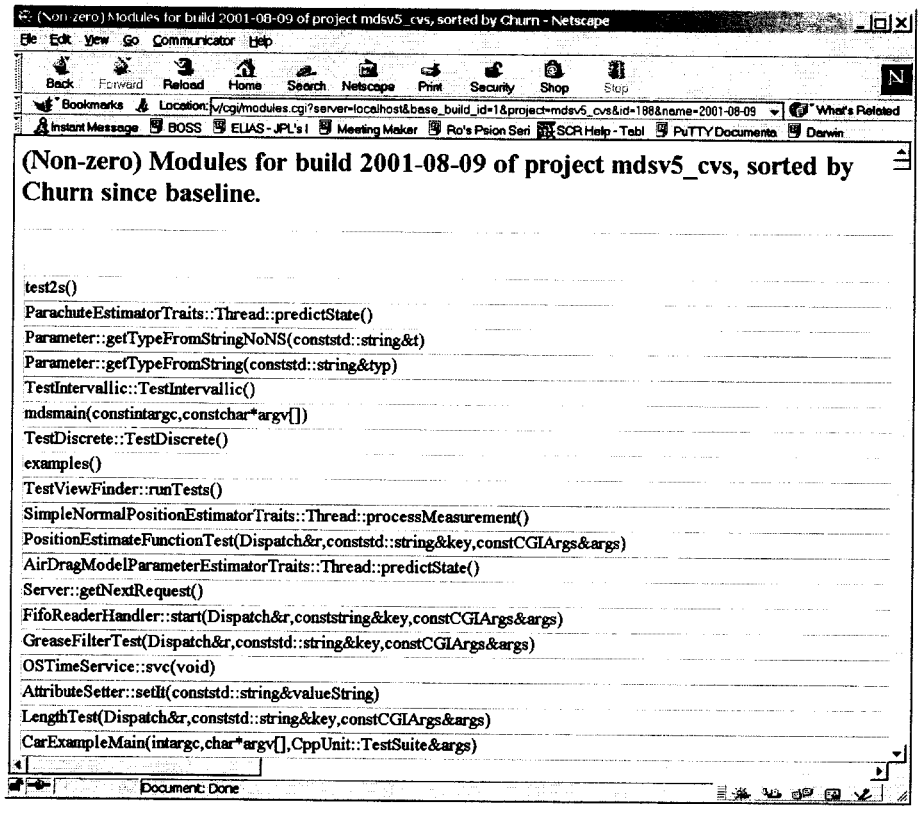
Motivation (cont'd)

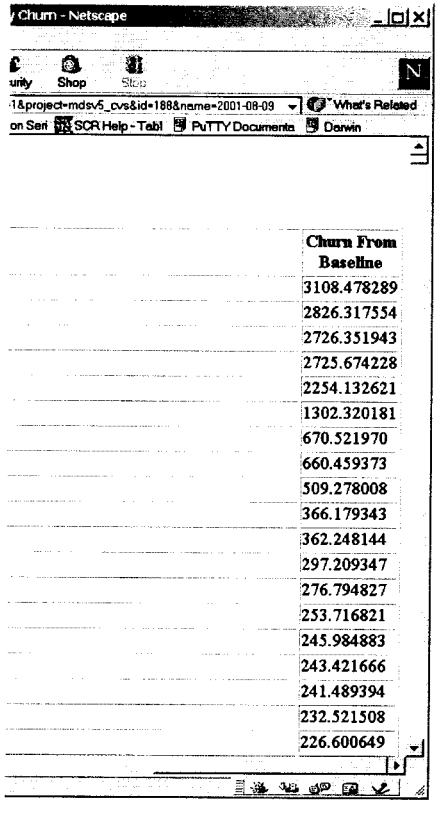
Measurement of Structural Evolution



Motivation (cont'd)

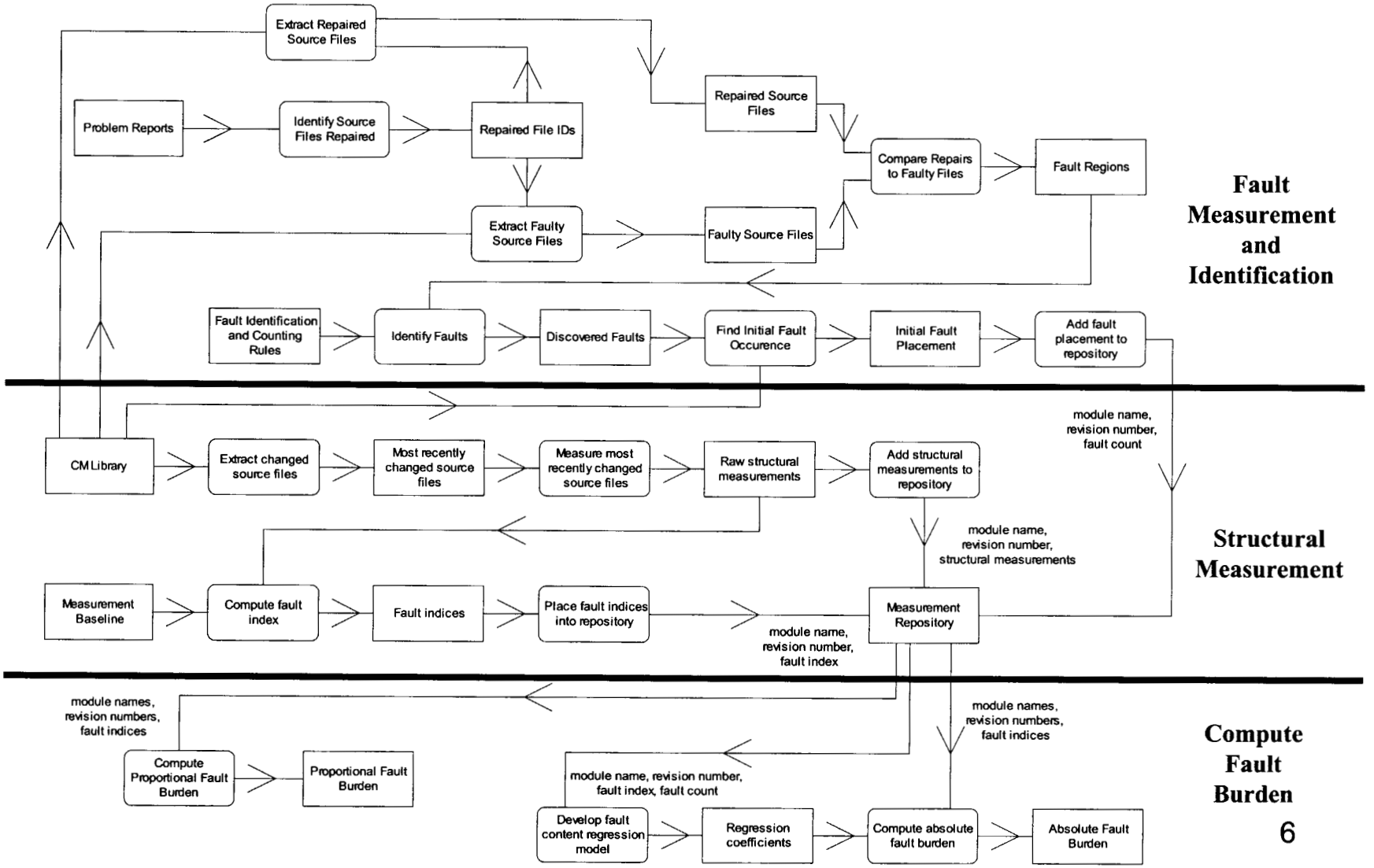
Structural Evolution at the Module Level





Motivation (cont'd)

Measurement Framework



Current State of Affairs

- No existing definition of fault in measurable terms
  - IEEE Standards
    - IEEE Std 729-1983, "IEEE Standard Glossary of Software Engineering Terminology"
    - IEEE Std 982.1-1988, "IEEE Standard Dictionary of Measures to Produce Reliable Software"
    - IEEE Std 1044-1993, "IEEE Standard Classification for Software Anomalies"
  - ODC
  - Previous work (Annual Oregon Workshop on Software Metrics, May 11-13, 1997)
  - Frankl, Hamlet, Littlewood, Stringini (IEEE TSE, vol. 24, no. 8, August 1998)

Approach

- Examine changes made in response to reported failures
- Base recognition/enumeration of software faults on the grammar of the software system's language
  - Faults found in executable, non-executable statements
- Fault measurement granularity in terms of tokens that have changed

Examples

- Example 1
  - Original statement: a = b + c * d;
  - Intended statement: a = b + c / d;
  - One token changed – "*" $\Rightarrow$ "/"
    - Coding error
  - Count number of faults as 1

Examples (cont'd)

- Example 2
  - Original statement: a = b + c * d;
  - Intended statement: a = b + (c * x) + sin(z);
  - Substantial difference between first and second statements
    - Reflects design rather than coding problem
  - Fault measurement method should reflect the degree of change

Identifying and Counting Faults

- Consider each line of text in each version of the program as a bag of tokens
  - If a change spans multiple lines of code, all lines for the change are included in the same bag
- Number of faults based on bag differences between
  - Version of program exhibiting failures
  - Version of program modified in response to failures
- Use version control system to distinguish between
  - Changes due to repair and
  - Changes due to functionality enhancements and other non-repair changes

Fault Identification Examples

- Example 1
  - Original statement: a = b + c;
    - B_1 = {<a>, <=>, <b>, <+>, <c>}
  - Modified statement: a = b - c;
    - B_2 = {<a>, <=>, <b>, <->, <c>}
  - $B_1 - B_2$ = {<+>, <-> }
  - $|B_1| = |B_2|$, $|B_1 - B_2| = 2$
  - One token has changed $\Rightarrow$ 1 fault

Fault Identification Examples (cont'd)

- Example 2
  - Original statement: a = b - c;
    - B_2 = {<a>, <=>, <b>, <->, <c>}
  - Modified statement: a = c - b;
    - B_3 = {<a>, <=>, <c>, <->, <b>}
  - $B_2 - B_3 = \{\}$
  - $|B_2| = |B_3|$, $|B_2 - B_3| = 0$
  - 1 fault representing incorrect sequencing

Fault Identification Examples (cont'd)

- Example 3
  - Original statement: a = b - c;
    - B_3 = {<a>, <=>, <c>, <->, <b>}
  - Modified statement: a = 1 + c - b;
    - B_4 = {<a>, <=>, <1>, <+>, <c>, <->, <b>}
  - $B_3 - B_4$ = {<1>, <+>}
  - $|B_3| = 6$, $|B_4| = 8$, $|B_4| - |B_3| = 2$
  - 2 new tokens representing 2 faults

Current Work

- Current Work
  - Application to JPL software development effort
    - Research
    - Production
  - Develop better models relating
    - Structural measurements of software evolution during development
    - Number and types of faults inserted